Managing Basis Risk with Index Insurance: The Case of West African Cotton Farmers*

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Abstract

Exposure to risk is one of life's few certitudes. For people who live in developing countries, where underdevelopment almost always extends to financial markets and where financial instruments to hedge against risk are fewer and further between than in industrialized countries, risk is even more prevalent. The rise of microfinance over the last 20 years has brought with it the development of financial instruments designed to protect the poor against some of the risk they face. We first develop an innovative index insurance contract for West African cotton producers, whose harvests are highly variable. The main feature of this contract – which we call the double-trigger insurance contract – is that relative to commonly used index insurance contracts, it considerably reduces the basis risk faced by West African cotton producers. We then describe an ongoing evaluation of the impacts of the double-trigger insurance contract in Mali and Burkina Faso, discussing training and research design at length.

Keywords: Index Insurance, Microinsurance, Crop Insurance, Risk and Uncertainty
JEL Classification Codes:

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Introduction

Exposure to risk, much like death and taxes in Benjamin Franklin's famous quip about the certainties of life, is one of life's few certitudes. Indeed, even for those of us who are fortunate enough to live in highly developed countries, where a host of financial instruments are available to hedge against the vagaries of life, the truth of the matter is that there will always remains a certain amount of risk which we are exposed to, because some risks are simply uninsurable (Gardner, 2009). Indeed, many contracts include a *force majeure* clause which renders a contract null and void in case of an act of war or terrorism or an act of God. This uninsured risk is commonly referred to as basis risk, or the risk that remains when using imperfect hedging.

For people who live in developing countries, where underdevelopment almost always extends to financial markets and where financial instruments to hedge against risk are fewer and further between, basis risk is even more prevalent. This is especially so for smallholder farmers, whose livelihoods are directly dependent on the risk and uncertainty associated with shifting agro-ecological conditions and largely unpredictable weather patterns. The presence of basis risk means that those smallholders often sink valuable resources which could otherwise be employed productively into hedging against risk (Scott, 1977), they refuse to adopt new technologies designed to improve their productivity, or they enter inefficient contracts that serve to as partial insurance mechanisms (Stiglitz, 1974).

The rise of microfinance over the last 20 years has brought with it the development of financial instruments designed to protect the poor in developing countries against some of the basis risk they

face.[1] Those financial instruments are generally referred to as "microinsurance" (Morduch, 2006). This paper looks at index insurance, i.e., microinsurance contracts wherein the payout to the insured by the insurer is tied to some measure which is easily verified by the insurer and cannot be tampered with by the insured – the so-called index.

The insurance contract we consider in the first part of this paper was designed for West African cotton farmers, whose cotton harvests are highly variable. The specific index this contract is tied to is the cotton yield in a given area (e.g., village, district, region, etc.). This is measured very precisely at various local and regional levels in some West African countries (e.g., Burkina Faso and Mali) because of the industrial organization of cotton in those countries, where the entire cotton production is purchased from producers by parastatals. Equally importantly, the area for which the index is measured can be chosen at a level beyond which individual cotton producers cannot tamper with. The former guarantees that everyone knows when the insurance will pay out and when it does not. The latter guarantees that moral hazard is all but eliminated. In practice, the insurance pays out if the average cotton yield in the area falls below a specific threshold.

In the second part of this paper, we describe an innovation we came up with when designing our index insurance contract which allows us to further reduce the amount of baseline risk West African cotton farmers are exposed to. Very simply, that innovation adds a second index to the insurance contract. Thus, the insurance pays out if two requirements are met: (i) the average cotton yield in a given producer's area falls below a certain threshold, and (ii) the average cotton yield in a given

[1] As Roodman (2011) notes, though microfinance is most famously associated with microloans, microfinance also has two other components, viz. microsavings and microinsurance.

producer's cooperative falls below another threshold. We discuss the reasons why this allows eliminating basis risk in the second half of this paper. In a nutshell, however, relative to single-index insurance contracts, double-index contracts completely eliminate false positives (i.e., situations wherein a cooperative with a yield above the area threshold receives a payout) while eliminating many false negatives (i.e., situations wherein a cooperative with a yield below the area threshold does not receive a payout).

In the third and last part of this paper, we describe an ongoing evaluation of the impacts of the insurance contract we develop in the previous part. To do so, we discuss both the training component of our project – West African cotton producers are not very familiar with the notion of insurance, let alone index insurance – and our research design. Our impact evaluation began in Mali in 2011-2012, but the Malian coup d'état of March 2012 has forced us to relocate our research project to neighboring Burkina Faso, whose market structure and agro-ecological conditions are very similar to those of Mali.

Institutional Setting

This research project began as a study of index insurance for cotton producers in Mali. The March 2012 coup d'état in Mali, however, has forced us to move the research project to neighboring Burkina Faso. Since we are only in the beginning stages of the Burkinabe portion of this research project, however, we only describe the Malian institutional setting in this paper. We discuss the advantages of moving the research project to Burkina Faso in the conclusion.

The cotton sector in Mali is characterized by two defining features. The first is that cotton producers are organized into cooperatives, and there are usually one or two cooperatives per village. The second is that the Malian cotton sector is a monopsony in that the country's entire marketed cotton production is purchased from producer cooperatives by a parastatal, the Compagnie malienne des textiles (CMDT).

As part of its relationship with cotton producers, the CMDT provides an input advance to each producer cooperative at the beginning of the cotton season which consists of some of the various inputs required to grow cotton, viz. seeds, pesticides, and fertilizers. The exact quantities of inputs are determined on the basis of the total number of hectares cultivated in cotton by members of the cooperative. The price of cotton is fixed at the start of the season so as to insure cotton producers are insured against price risk (Barrett, 1996; Bellemare et al., 2012). Cotton producers then make their production decisions.

At harvest time, cotton yields are weighted and recorded by the CMDT. Here, the incentives of producers are aligned with those of the parastatal: given that producers are paid a fixed price per kilogram of output and that the CMDT is the sole buyer of cotton, producers have no incentive to under-report their output. The CMDT then purchases a producer's entire cotton production.

There is a twist, however. Indeed, a producer's revenue – the value of his cotton production – is deposited in a bank account at the Banque nationale de développement agricole (BNDA). A producer cannot withdraw his revenue from his BNDA account until his cooperative repays the value of the input

package it has received from the CMDT. Because of joint liability (Besley, 1995; Ghatak and Guinnane, 1999), when a cooperative member cannot repay his portion of the input package, other cooperative members will step in to cover his share. In recent years, this joint liability has been the source of many tensions within cooperatives and villages.

Index Insurance for West African Cotton Producers

Sources of Basis Risk

Consider the following representation of cotton yield for cotton-producing household h in insurance coverage zone z in period t:

$$y^*_{hzt} = \bar{y}^*_{zt} + \epsilon_{hzt}, \qquad (1)$$

Define y^*_{hzt} and $\bar{y}^*_{zt}$ such that (i) $y^*_{hzt} = y_{hzt} - \mu_{hz}$, and (ii) $\bar{y}^*_{zt} = y_{zt} - \mu_z$. Definition (i) says that an asterisk denotes a household's cotton yield expressed as a deviation from the household's average cotton yield over the time period considered, and definition (ii) says that an upper bar denotes a cooperative's cotton yield expressed as a deviation from the zone's average cotton yield over the same time period. Given those definitions, then, equation (1) says that the cotton yield of household h in insurance coverage zone z in period t can be decomposed into two terms: a correlated component, which is correlated across all the households in a given insurance coverage zone, and an idiosyncratic component, which is specific to each household.

The variance of the idiosyncratic component ϵ_{hzt}, $V(\epsilon_{hzt})$, depends on the geographic scale of the insurance zone considered. As that geographic scale shrinks to the scale of the household, $V(\epsilon_{hzt}) = 0$. Suppose now that $\bar{y}^*_{zt}$ is not measured directly but instead predicted with an index signal S_{zt}, such that

$$\bar{y}^*_{czt} = f(S_{czt}) + \upsilon_{czt}. \quad (2)$$

This introduces an additional source of deviation between household-level outcomes and the index. Graphically, idiosyncratic and correlated risk can be represented as in figure 1, which also distinguishes basis from insured risk. In figure 1, the geographic scale of the index shifts the double line: as the scale of the index decreases to cover a smaller geographical area, the double line moves to the left, and as the scale of the index increases to cover a broader geographical area, the double line moves to the right.

There are many reasons why one should worry about basis risk. The most important of those reasons is that the partial insurance that is the counterpart of basis risk might not be sufficient to encourage prudential risk-taking behavior such as the adoption of new technologies. In addition, basis risk creates something akin to ambiguity (or Knightian uncertainty; Gilboa, 2009) in the eyes of cotton producers, and there is some evidence that individuals are ambiguity-averse (Fox and Tversky, 1995).

Three Types of Index Insurance Contracts

Before describing the innovative contract we developed for West African cotton farmers, we start by considering three types of index insurance contracts:

1. Lump-sum indemnity contracts,

2. Single strike point contracts, and
3. Double strike point contracts.

A *lump-sum indemnity contract* is a contract such that

$$p_{hzt} = \max\{S_z - y_{zt}, 0\}, \tag{3}$$

where p_{hzt} denotes the insurance payout received by household h in insurance coverage zone z in period t, S_z denotes a predetermined strike point (i.e., the level below which the insurance pays out), and y_{zt} denotes the average yield in insurance coverage zone. Quite simply, a lump-sum indemnity contract pays out if and only if the average yield in the zone in which household h is located falls below S_z, and the payout is a function of the average yield shortfall relative to the strike point.

A *single strike point contract* is such that

$$p_{hzt} = \begin{cases} 0 \text{ if } y_{zt} \geq S_z \\ L_1 \text{ if } y_{zt} < S_z \end{cases}, \tag{4}$$

where L_1 is a lump-sum payment. The difference between a lump-sum indemnity contract and a single strike point contract lies in whether the payout is a function of the of the average yield shortfall relative to the strike point, as in the case of a lump-sum indemnity contract, or not, as in the case of a single strike point contract, which only pays out a fixed, predetermined amount of money.

Lastly, a *double strike point contract* is such that

$$p_{hzt} = \begin{cases} 0 \text{ if } y_{zt} \geq S_{z2} \\ \frac{L_1}{2} \text{ if } y_{zt} \in [S_{z1}, S_{z2}) \\ L_1 \text{ if } y_{zt} < S_{z1} \end{cases}. \quad (5)$$

Where S_{z1} and S_{z2} are predetermined strike points and $S_{z1} < S_{z2}$. Assuming S_z in equations (3) and (4) is the arithmetic mean of S_{z1} and S_{z2}, i.e., $S_z = (S_{z1} + S_{z2})/2$, a double strike point contract has the following properties. First, its structure is much simpler than a lump-sum indemnity contract, since the producer either receives L_1, $L_1/2$, or nothing. Second, it pays out more often relative to a single strike point contract given that $S_{z1} < S_z$, though those more frequent payouts are also less than what they are under a single strike point contract.

The Double-Trigger Insurance Contract

The innovation we bring to the table is the double-trigger insurance contract (2TIC), which is such that

$$p_{hczt} = \begin{cases} 0 \text{ if } y_{zt} \geq S_z \text{ or } y_{czt} \geq S_{cz} \\ L_1 \text{ if } y_{zt} < S_z \text{ and } y_{czt} < S_{cz} \end{cases}, \quad (6)$$

where the subscript c denotes the cooperative c within insurance coverage zone z to which household h belongs and S_{cz} and S_z respectively denote cooperative- and zone-specific strike points, so that the insurance pays out L_1 if and only if the average yield in the cooperative falls below a certain cooperative-specific threshold and the average yield in the zone falls below a certain zone-specific threshold.

Relative to the double strike point contract described in the previous section, the 2TIC has two nice advantages. First off, it completely eliminate “false positives,” or situations wherein a cooperative whose yield is above the zone-specific threshold receives a payout, i.e., situations where an

"undeserving" cooperative receive a payout simply because it was lucky enough to find itself in a low-yield zone. Second, it reduces the incidence of "false negatives," or situations wherein a cooperative whose yield is below the zone-specific threshold does not receive a payout, i.e., situations where a "deserving" cooperative does not receive a payout because it was unlucky enough to find itself in a high-yield zone.

Let us now consider the relative merits of the contract types discussed above, and let us treat lump-sum indemnity contracts as our baseline, i.e., the contract relative to which other contracts are assessed ex ante. For cotton farmers in Peru, the single strike point contract turned out to be much more attractive to producers. After proposing a single strike point contract, take-up of the insurance tripled (CITE). This occurred despite the fact that under a single strike point contract, the lump-sum payment does not increase as a function of the loss. Presumably, the increased take-up occurred because of the single strike point contract's relative simplicity, and because it creates a focal point for farmers. Relative to a single strike point contract, a double strike point contract is cheaper.

Let us now look at all three contacts side by side. Table 1 illustrates the Ntenkoni agricultural production zone in the Dogo sector, where average yield is equal to 1,042 kilograms of cotton per hectare (kg/ha). In this case, the commercial premia include a 30-percent markup over the actuarially fair premium.

Relative to the single strike point contract, the relative premia of double strike point contracts are 45 to 50 percent lower. This is because payments are kept lower than those of single strike point contracts for low – but not catastrophic – yields. Moreover, witness how the premium of the double strike point contract closely resembles that of the lump-sum indemnity contract. Another problem with the lump-sum indemnity contract is that it pays very rarely. For the analysis we conducted, such a contract would pay once every 25 to 40 years, which would likely cause trust problems. Still, preliminary discussions indicated that a single price with local strike points would make sense to farmers. Lastly, note that the 2TIC allows considerably reducing basis risk. Indeed, as noted above, 2TICs completely eliminate situations where cooperatives with yields above the strike point receive payments (i.e., false positives) while reducing the number of cases wherein of cooperatives fail to receive a payment even when their yield is below the strike point (i.e., false negatives).

Ultimately, we settled on the 2TIC for our research project with a zone-level trigger of 900 kg/ha and coop-specific triggers varying between 264 and 913 kg/ha (during a preliminary stakeholder meeting in Bamako, farmers indicated that 750 kg/ha was a critical threshold below which they could not repay their 95,000 FCFA/ha input loans).

Table 2 and Figure 4 compare a hypothetical single strike point contract (A) with a hypothetical 2TIC (C). Note that contract C has a much higher "success rate": under contract A, the cooperative receives a payout in only 54 percent of the cases where its yield falls below the strike point. Under contract C, the cooperative receives a payout in 98 percent of such cases. The drawback of the 2TIC is that it is a relatively complex financial instrument, and that the concept may be difficult to convey. The next

section discusses the importance of training farmers so that they understand what the 2TIC does and does not do.

Implementation

Training

Having settled on the 2TIC for our research project, we had to think carefully about our project's education component. Indeed, though Malian cotton farmers have some experience with insurance – the CMDT forces them to buy life insurance so as to make sure that their families can repay the input advance they receive every year – the 2TIC remains a complex financial product relative to a lump-sum indemnity contract, a single strike point contract, or a double strike point contract.

We started with a first stakeholder workshop in October 2010 to announce and explain the project in as detailed a way as we could at that time. The workshop convened people from the Index Insurance Innovation Initiative, PlaNet Guarantee (our implementing partner), Oxfam, Allianz, etc., but also a number of representatives from producer organizations. As part of the workshop, we first discussed:

1. Why an index insurance contract for cotton producers?
2. What is an index insurance contract?
3. A description of the 2011-2012 pilot.

We then split the attendance into two discussion groups: one on institutional coordination, and one on the implementation of the index insurance.

As we mentioned above, the representatives from producer organizations seemed to be familiar with the idea of insurance, given that the CMDT makes the purchase of life insurance compulsory. One representative likened index insurance to an amulet one would purchase for protection when traveling. It was particularly interesting to witness stakeholders' reactions when we explained all possibilities, especially the possibility where one's cooperative does not do well but the zone does well, so that one does not receive a payout.

We then held a second workshop in March 2011. The first half of that second workshop was to give a broad overview of the idea behind index insurance, the 2TIC retained for impact evaluation, the sectors to be studied, the sampling methodology, the pricing structure of the contract, and the timeline for the project.

The second half of the workshop aimed at training eight trainers recruited by PlaNet Guarantee and Oxfam. These trainers would then be in charge of training people on the ground: 16 people at the zone level, and 136 people at the village level, called village information people (VIPs). By the end of their training, the eight trainers were expected to understand

1. The idea of index insurance
2. The idea of area-based yield insurance
3. The characteristics of the contract retained for implementation
4. The sector, zones, and cooperative selection criteria

5. The channels through which the insurance contract is purchased and through which it pays out
6. The risks covered and those not covered

The second half of the workshop was split into three sessions. The first session was devoted to explaining the notion of average and to applying it to an agricultural production zone. This was done using colored balls. In this session, the trainers also learned about the determinants of area yield, and they were trained on how to explain the concept to the VIPs. Figure 2 was used to explain the notion of average, though when training VIPs, the trainers were to use real bags of cotton, they would split cotton producers in several groups, and they would use play money.

The second session was devoted to explaining the notion of insurance. Participants were allocated between hypothetical cooperatives. Then, in a bag labeled “cooperative yield,” ten colored balls were placed, with each color representing an outcome: black (1) for very low, red (2) for low, gray (3) for normal, green (2) for high, and blue (1) for very high yields. Cooperatives then decided whether to buy the insurance contract, and a simulation was run with the colored balls in which participants were shown how to compute (i) gross cooperative income, given the random draw and a price per kg of 200 FCFA; (ii) cooperative debt conditional on whether or not insurance was purchased; and so (iii) coop’s net income. The same idea was then repeated for the second trigger, i.e., the yield at the zone level, using additional colored balls: blue (1) if the zone-level yield is 200 kg/ha below, yellow (2) if it is equal, and black (1) if it is 200 kg/ha above the coop-level yield.

After introducing the idea of coop-level yield and the idea of zone-level yield sequentially, the concept of 2TIC was introduced with the following parameters:

1. premium of 9,500 FCFA/ha/person

2. Two triggers (cooperative- and zone-level triggers)

3. Payout of 95,000 FCFA/ha/person (i.e., enough to cover input package)

Key terms were the introduced in Bambara, and the insurance purchase procedure and channel were explained. After the workshop, each trainer was going to be in charge of training VIPs and visiting each coop for a training session during which a vote would take place regarding whether the cooperative wanted to buy the insurance contract. This process was to be supervised by Oxfam and PlaNet Guarantee via email, telephone, and field visits.

The third and last session was devoted to another simulation by the participants, to a discussion of the technical terms, to a questions-and-answers period, and to getting the participants' feedback. We also wrote the storyline of a comic strip aimed at explaining the idea behind our insurance product, had the comic strip made, and the storyline translated into Bambara for the use of cotton producers. Finally, a training manual and a training brochure were written.

Evaluation

This section only briefly describes the research design we adopted, given that we are keeping the actual discussion of our empirical results for another paper.

We felt it was important to get a clear sense of the welfare impacts of the 2TIC, which is why we adopted an experimental design and conducted a randomized controlled trial of the 2TIC (Duflo et al., 2008; Barrett and Carter, 2010).

We initially wanted to look at 100 cooperatives, half of which would be randomly assigned to the treatment group, with the remaining half assigned to the control group. Unfortunately, the reinsurer we were working with could not price the contract for more than 86 of those cooperatives due to a lack of data. Moreover, because we could not force treatment-group cooperatives to purchase the 2TIC, we had assigned the 86 selected cooperatives to a 28-cooperative control group and a 58-cooperative treatment group. For those cooperatives in the treatment group, we also added a second layer of randomization to our research design by offering a random (and temporary) encouragement which took the form of a 0, 25, or 50 percent discount on the actuarially fair premium. Because producers value fairness, when two cooperatives within a given zone were to offered the 2TIC, they were to pay the same premium – in that case, we mimicked the encouragement designed by varying the strike points instead.

Our impact evaluation is thus concerned with the following questions. At the intensive margin, do insured cotton producers increase area planted and revenue? At the extensive margin, are there farmers who were not planting cotton who start doing so and join the cooperative? If so, through which mechanism does this happen? Is it via the fact that the credit contract with the CMDT involves less risk, or are they directly induced to participate by the insurance contract? Finally, as regards financial markets, do the terms of the credit contract between the CMDT and individual cooperatives change as a

result of the 2TIC? And are social tensions due to the presence of joint liability alleviated because of the 2TIC? And in the long run, we are concerned with whether more stable income streams will improve household welfare and increase human capital accumulation among the children of the insured by increasing investments in nutrition and education. To that end, our survey also collected anthropometric measures. Finally, we ran framed field experiments aimed at eliciting the risk and ambiguity preferences of a randomly selected subset of 330 cotton producers within both the treatment and control groups. The information collected will allow fine tuning the contract in the future as well as learning about fundamental behavioral questions.

Conclusion

This article has first described the double-trigger insurance contract, an innovative financial instrument we developed to reduce the basis risk faced by West African cotton producers. In this context, whether the insurance pays out is linked to two indices – the average yield in the cooperative to which the producer belongs to, and the average yield in the production zone within which the producer's cooperative is located.

Relative to an index insurance where insurance payout is linked to a single index, the double-trigger insurance contract has two advantages. First off, it completely eliminates situations wherein a cooperative whose yield is above the zone-specific threshold receives a payout, i.e., false positives. Second, it considerably reduces the incidence of situations wherein a cooperative whose yield is below the zone-specific threshold does not receive a payout, i.e., false negatives. Perhaps more importantly, it significantly reduces the amount of basis risk West African cotton producers are exposed to relative to more common, single-index contracts.

Second, this paper has described an ongoing evaluation of the impacts of the double-trigger insurance contract described in the first half of the paper. Because the financial instrument we developed for West African cotton farmers is complex relative to life insurance (i.e., the only form of insurance they are familiar with), a great deal of time was spent on training the cotton producers in our sample so that they would know exactly what they are and are not getting from the insurance contract if (i) the cooperative to which they belong to happened to be offered the contract as part of the randomized controlled trial we are running to study the impacts of the insurance, and (ii) they and their fellow cooperative members agreed to purchase the insurance product.

We closed our discussion of our research project by briefly describing our progress on the impact evaluation. Because this project began in fall 2010, we managed to collect one round of data before the March 2012 coup d'état in Mali. Since then, because our funding comes from the US Agency for International Development (USAID), it has not been possible for us to spend any more grant money in Mali. As of writing this paper, we have moved our research project to neighboring Burkina Faso, where the cotton market structure is very similar to Mali's – a parastatal, Sofitex, is in charge of purchasing the entirety of the country's cotton production – and where agro-ecological conditions are comparable. Though this did represent a setback relative to our goal of conducting a longer (i.e., three-year) impact evaluation, the silver lining is that conducting the same study in a second country will help with external validity.

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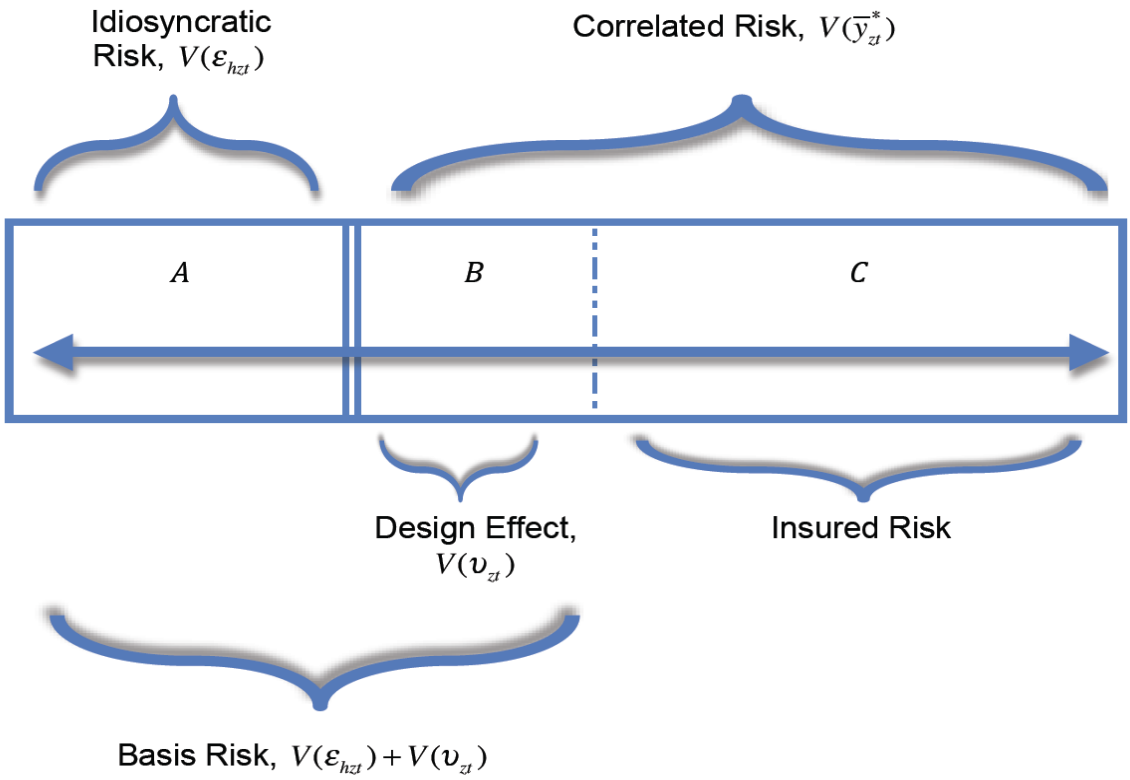

Figure 1. Idiosyncratic vs. Correlated Risk and Basis vs. Insured Risk.

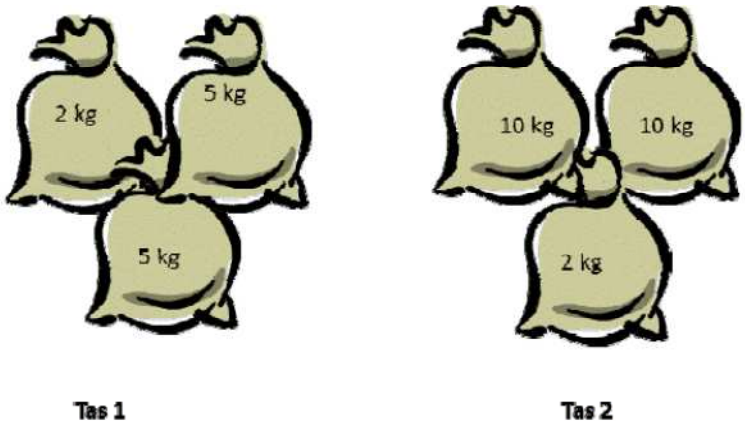

Figure 2. Teaching the Notion of Average Using Bags of Cotton.

	Secteur de **Bougouni** à rendement moyen **faible**					
	Très faible (400 kg/ha)	Faible (650 kg/ha)	Normal (900 kg/ha)	Fort (1100 kg /ha)	Très fort (1400 kg/ ha)	
	🔴	🟠 🟠	⚪ ⚪ ⚪ ⚪	🟢 🟢	🟡	
🔵	200	450	700	900	1200	Rendement de la ZPA (kg/ ha)
🟡	400	650	900	1100	1400	
⚫	600	850	1100	1300	1600	

Figure 3. Simulating Two Strike Points Using Colored Balls During Training.

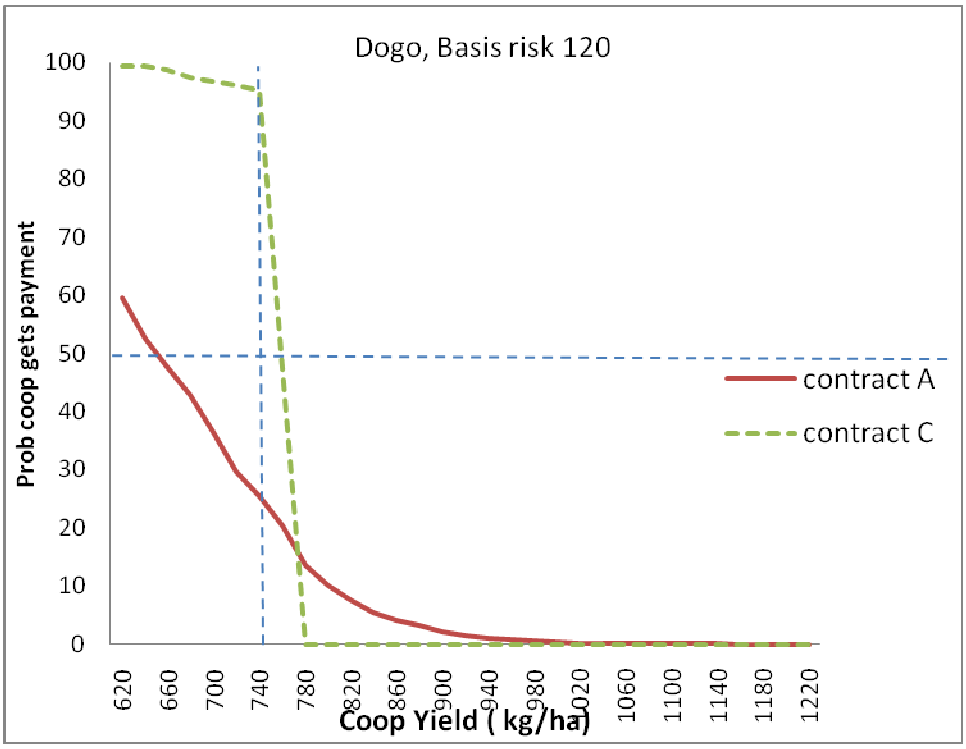

Figure 4. Single Strike Point (A) vs. Double-Trigger Contract (C).

Table 1. A Comparison of Lump-Sum Indemnity, Single Strike Point, and Double Strike Point Contracts for the Ntenkoni agricultural production zone in the Dogo region of Mali.

	Lump-Sum	Single Strike Point	Double Strike Point
First Strike Point	850	750	750
Second Strike Point	-	-	500
Commercial Premium	3,187	5,854	3,208
Cotton Yield (kg/ha)	Indemnity Payment (FCFA/ha)		
900	0	0	0
850	0	0	0
800	11,050	0	0
750	22,100	95,000	50,000
700	33,150	95,000	50,000
650	44,200	95,000	50,000
600	55,250	95,000	50,000
550	66,300	95,000	50,000
500	77,350	95,000	95,000
450	88,400	95,000	95,000
400	99,450	95,000	95,000

Table 2. A Comparison of Single Strike Point vs. Double-Trigger Contracts.

Single Strike Point (A)	
Zone Strike Point	750
Probability of Payout	3%
Pure Premium (kg/ha)	15
Price (FCFA/ ha)	2567
Double Trigger (C)	
Cooperative Strike Point	750
Zone Strike Point	1000
Probability of Payout	5%
Pure Premium (kg/ha)	26
Price (FCFA/ ha)	4364